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Baghdasarian

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(54) **REDUNDANT FUSE WIRE RELEASE DEVICE**

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(51) **Int. Cl.**

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B64G 1/22	(2006.01)
H01H 85/046	(2006.01)
H01H 85/00	(2006.01)
B64G 1/44	(2006.01)
B64G 1/66	(2006.01)

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CPC ***B64G 1/222*** (2013.01); ***H01H 85/0047*** (2013.01); ***H01H 85/0052*** (2013.01); ***H01H 85/046*** (2013.01); *B64G 1/44* (2013.01); *B64G 1/66* (2013.01)

(58) **Field of Classification Search**

CPC B64G 1/645; B64G 1/222; B64G 1/44; B64G 1/66; G05G 17/00; Y10T 74/11; Y10T 403/11; Y10T 403/21; H01H 85/046; H01H 85/0047; H01H 85/0052

USPC 337/142, 1, 401, 5, 140, 159, 182, 183, 337/290, 296, 297, 416; 403/2, 28; 74/2

See application file for complete search history.

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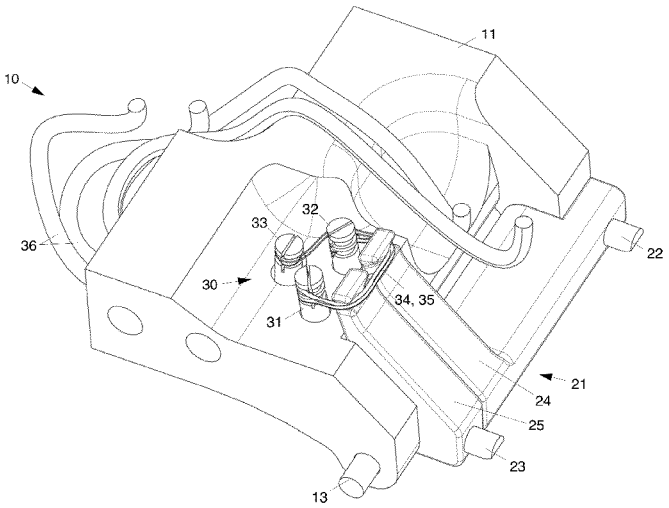
Primary Examiner — Anatoly Vortman

(74) *Attorney, Agent, or Firm* — Kenneth W. Float

(57) **ABSTRACT**

Redundant fuse wire apparatus and redundant release devices, such as those used to release deployable appendages, such as solar array and reflectors disposed on satellites, and the like. An exemplary redundant release device comprises a restraint release mechanism having one or more restraint release arms, a redundant release device comprising a segmented spool having a plurality of segments that are constrained from separating by spring restraint tape releasably secured to the restraint release arms, a redundant fuse wire assembly comprising primary and redundant positive contacts, a common negative contact, primary and redundant fuse wires respectively connected between the primary positive and common negative contacts and the redundant positive and common negative contacts that respectively wrap around the opposed positive contact and the restraint release arms, and an electrical power source for heating and severing the fuse wires.

17 Claims, 9 Drawing Sheets



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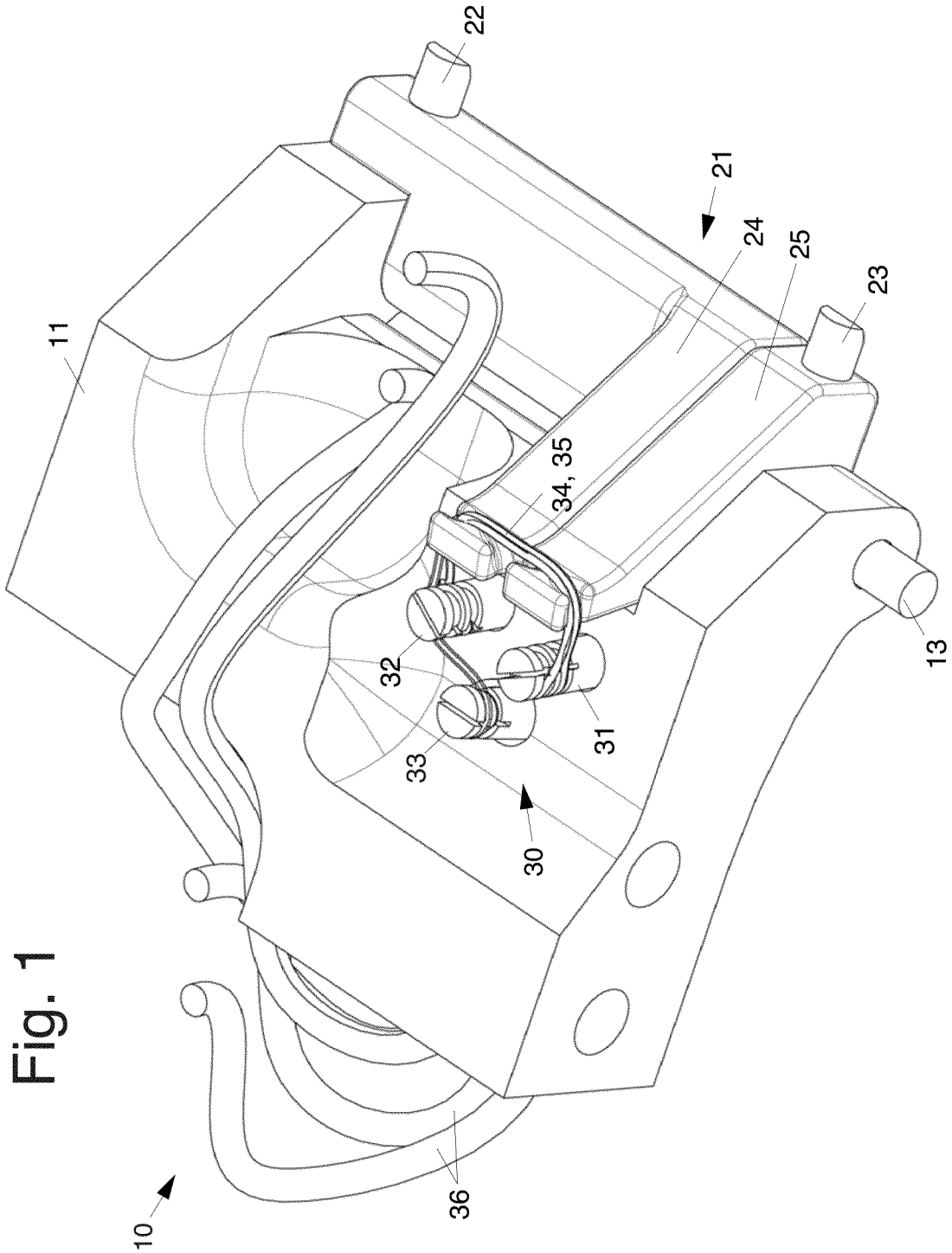


Fig. 1

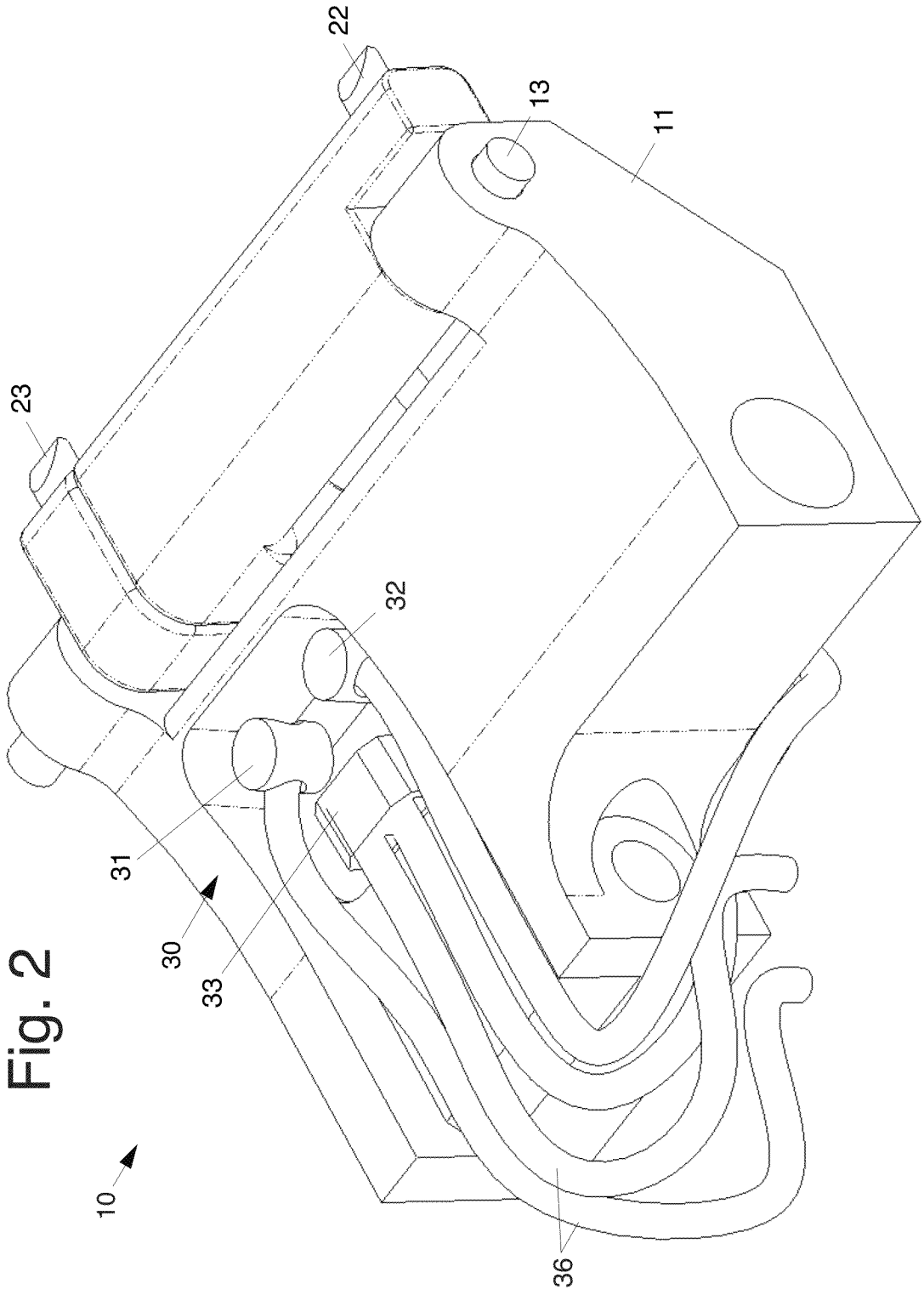


Fig. 2

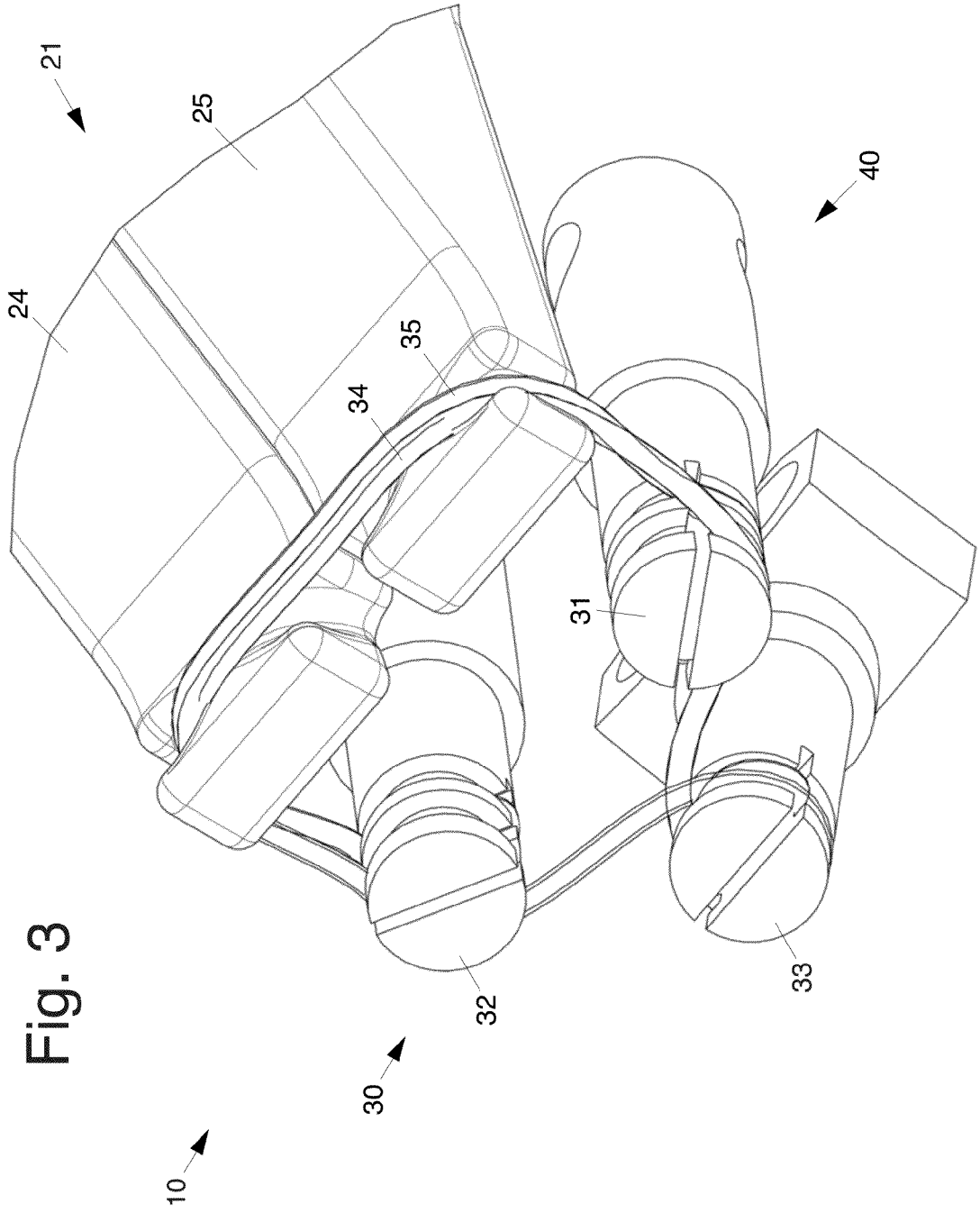
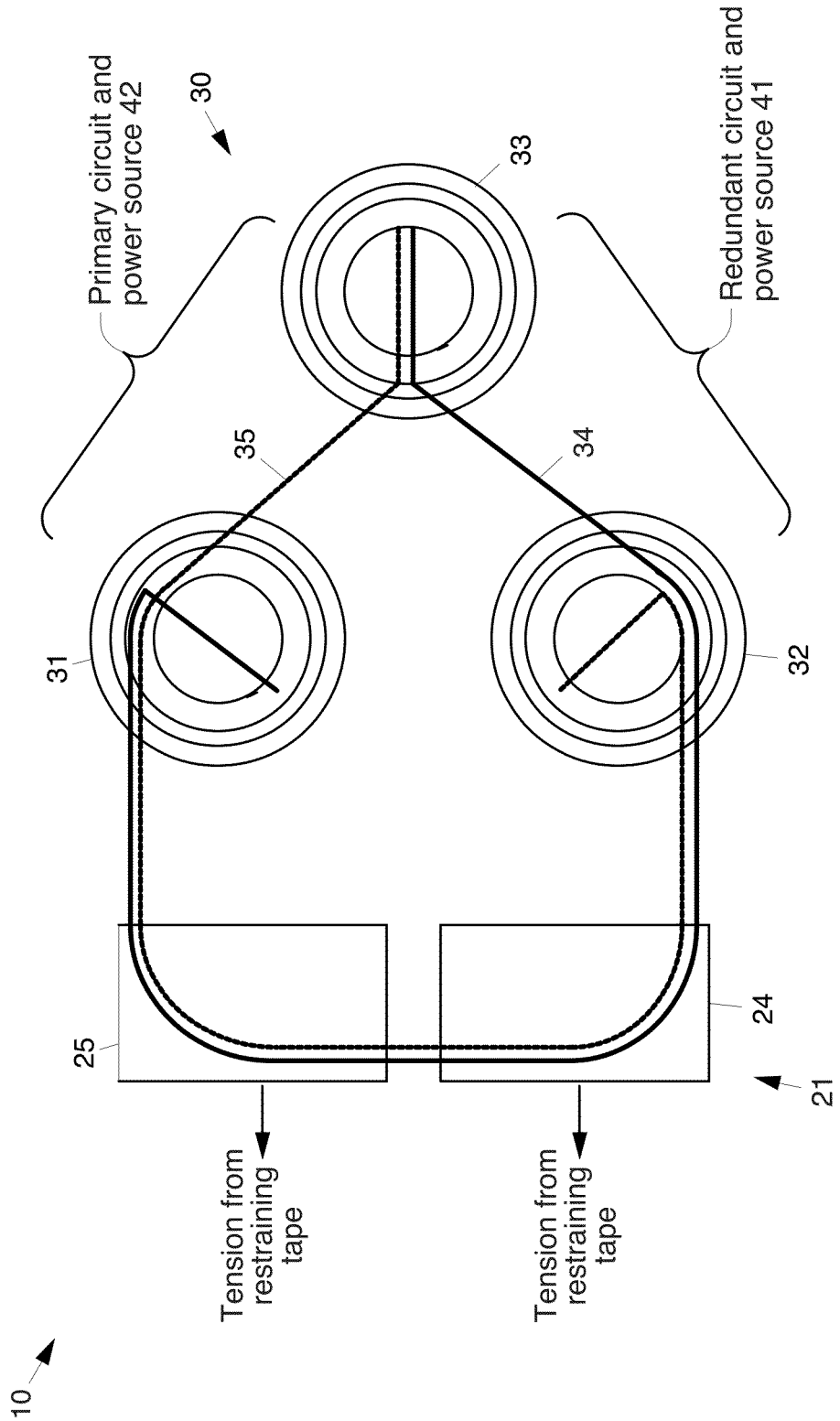


Fig. 3

Fig. 4


Primary circuit and power source 42
30
33
Redundant circuit and power source 41
35
34
31
32
25
24
21
Tension from restraining tape
Tension from restraining tape
10

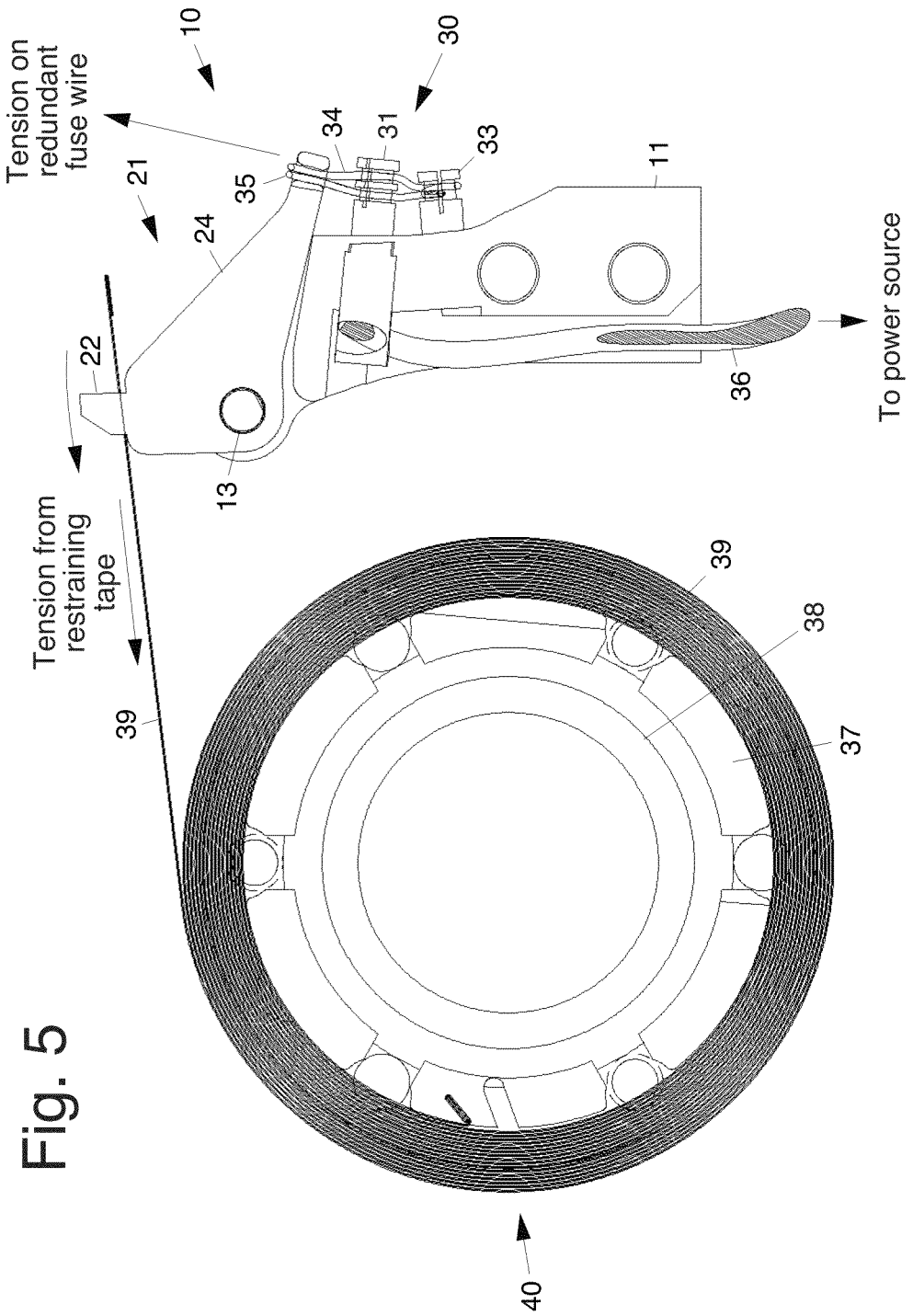

Tension on redundant fuse wire
10
30
34
31
33
21
35
11
24
22
To power source
36
13
Tension from restraining tape
39
39
38
37
40

Fig. 5

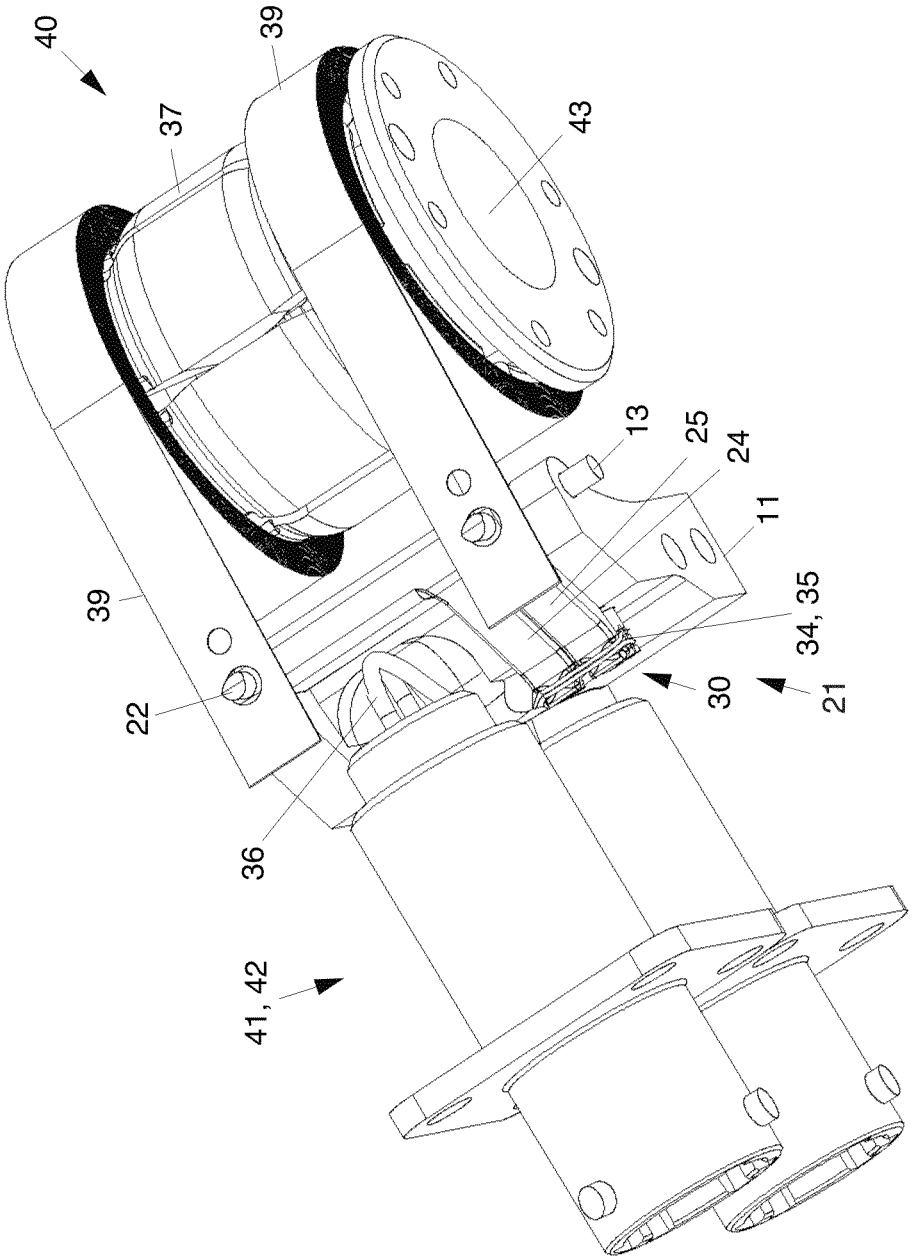
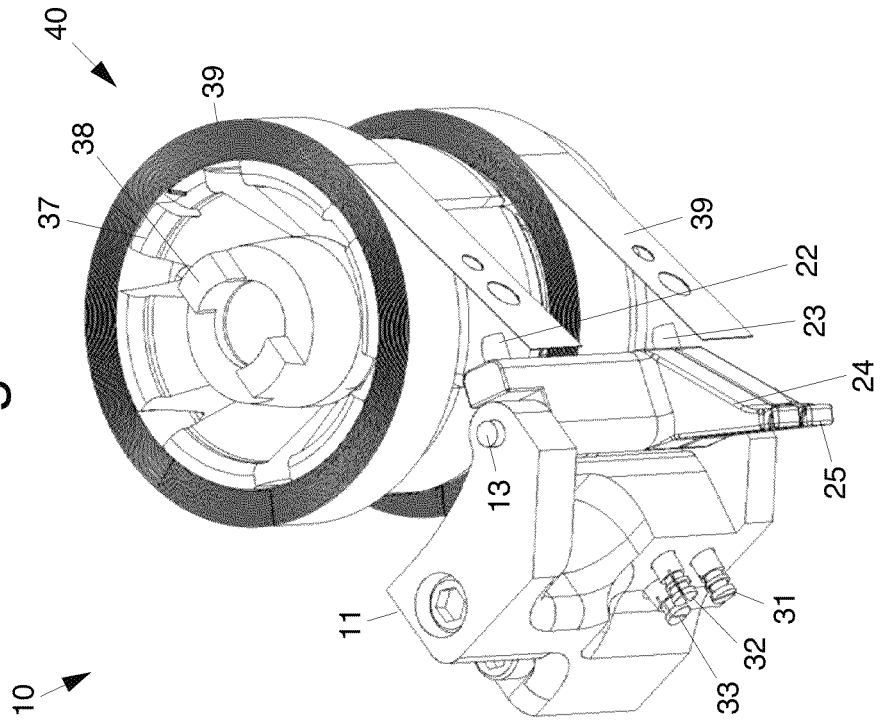


Fig. 6a

Fig. 6c


40
39
38
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22
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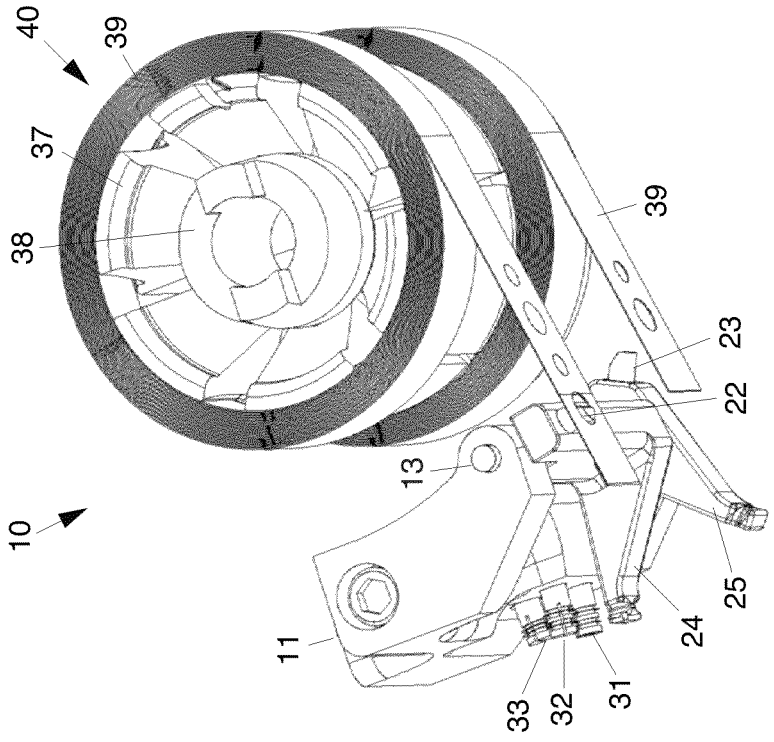
13
11
31
32
33
10

Fig. 6b


40
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38
39
23
22
13
25
24
11
33
32
31
10

Fig. 7a

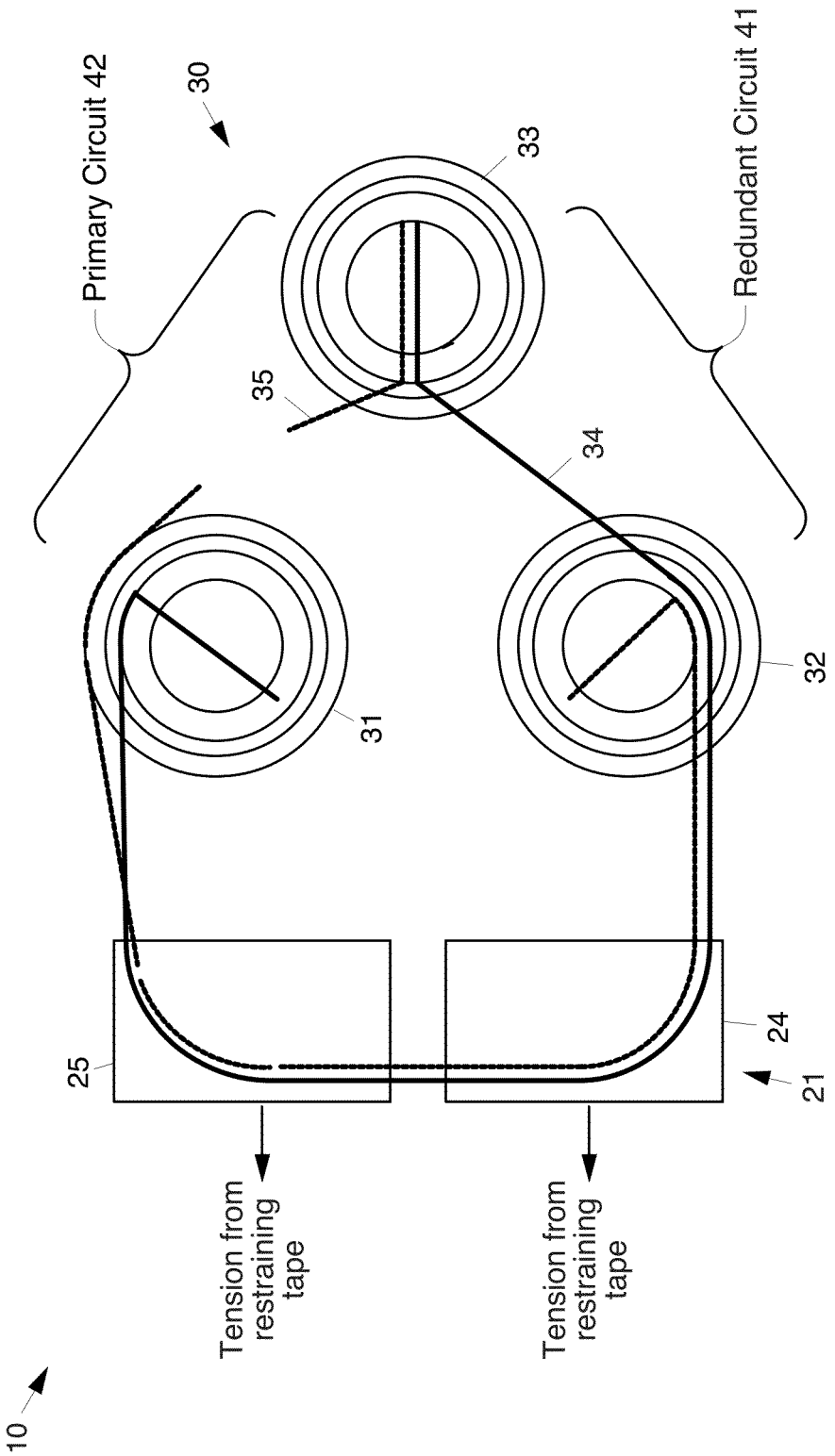
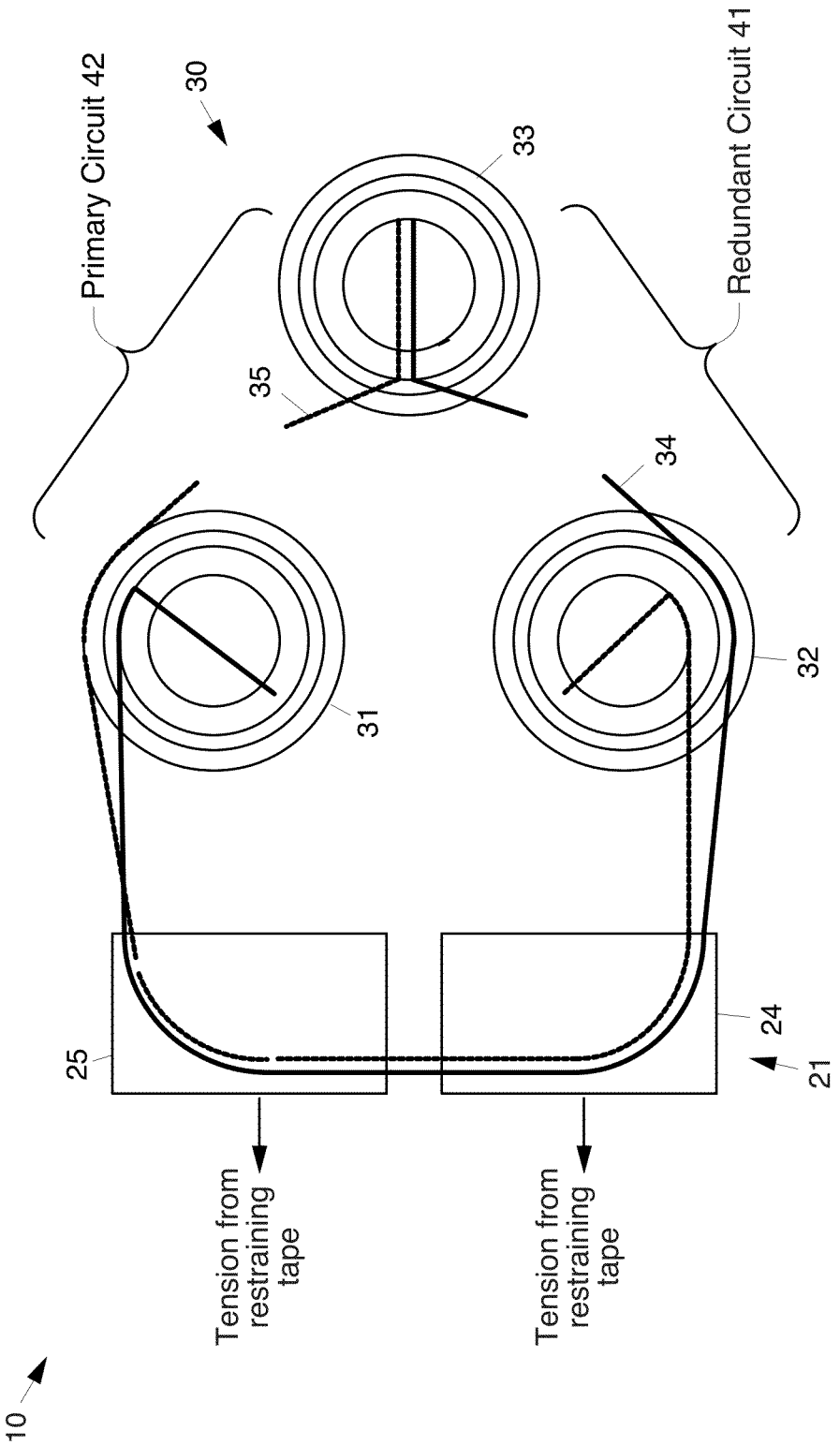

Primary Circuit 42
30
33
Redundant Circuit 41
35
34
31
32
25
24
21
Tension from restraining tape
Tension from restraining tape
10

Fig. 7b


Primary Circuit 42
30
33
Redundant Circuit 41
35
34
31
32
25
24
21
Tension from restraining tape
Tension from restraining tape
10

REDUNDANT FUSE WIRE RELEASE DEVICE

BACKGROUND

The present invention relates generally to release devices, and more particularly, to a redundant fuse wire release device and redundant fuse apparatus that may be used to stow or release items such as solar arrays, antenna positioning mechanisms, reflectors, and the like, found on satellites, space stations, and spacecraft, for example.

Conventional prior art non-explosive release apparatus, such as a separation spool device, for example, is used to stow or release a captured member that constrains deployment of a spacecraft element, for example, such as a solar array, in a stowed position. In such apparatus, a single fuse wire acts as a locking member that fastens a tensioned member wrapped in tension around a split spool. When the tensioned member is under tension, the split spool is clamped to a portion of the device to be deployed (the captured member) which prevents deployment of the captured member, such as a solar array. Once the release device is actuated, the fuse wire unlocks by self-destructing, thereby releasing the tensioned member to unclamp the captured member and allow deployment.

However, such a single fuse wire locking member is subject to self-unlocking resulting from mechanical failure. The single locking member (fuse wire) can fail due to mechanical stress and cause premature release of the device. An electrical failure can also prevent the device from releasing if inadequate current flows to melt the fuse wire upon actuation.

To overcome the limitations of this conventional single fuse wire locking member, a redundant fuse for use with in a split spool device was developed by the assignee of the present invention is disclosed in U.S. Pat. No. 6,133,818, issued to Hseih, et al., and is an example of a redundant fuse wire design for an application similar to that of the present invention.

The redundant fuse wire design disclosed in U.S. Pat. No. 6,133,818 uses three individual fuses configured in a triangular shape preventing a round disk from release. It requires cutting two of three fuses to release the disk, and it prevents premature release if one fuse is accidentally cut, thus, it is single point fault tolerant.

The shortcoming of this redundant fuse wire design is that third fuse does not always get cut upon actuation, and thus it could potentially cause release hang up.

Also, with three fuses rigidly connected to three contacts, depending upon the accuracy of fuse wrapping tension, the load may not be equally shared by all there fuses, therefore it is possible for one or two fuses to be overloaded while the other is not loaded at all, resulting in a potential for fuse overload

In view of the above, it would be desirable to have a improved redundant fuse wire release device and redundant fuse apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the present invention may be more readily understood with reference to the following detailed description taken in conjunction with the accompanying drawing figures, wherein like reference numerals designate like structural element, and in which:

FIG. **1** illustrates exemplary redundant fuse wire release device;

FIG. **2** illustrates a bottom view of the redundant fuse wire release device;

FIG. **3** illustrates an enlarged view of a redundant fuse wire assembly that may be used in the redundant fuse wire release device;

FIG. **4** illustrates an enlarged plan view of the redundant fuse wire assembly;

FIG. **5** illustrates an enlarged side view of the redundant fuse wire release device;

FIG. **6***a*-**6***c* show engagement and disengagement of the restraint tapes with the release arms; and

FIGS. **7***a* and **7***b* illustrate the sequence of events performed when actuating the redundant fuse wire release device.

DETAILED DESCRIPTION

Referring to the drawing figures, FIG. **1** illustrates exemplary redundant fuse wire release device **10**. FIG. **2** illustrates a bottom view of the redundant fuse wire release device **10**. FIG. **3** illustrates an enlarged view of a redundant fuse wire assembly **30** that may be used in the redundant fuse wire release device **10**. FIG. **4** illustrates an enlarged plan view of the redundant fuse wire assembly **10**. FIG. **5** illustrates an enlarged side view of the redundant fuse wire release device **10**. FIG. **6** shows engagement and disengagement of restraint tapes from release arms. FIGS. **7***a* and **7***b* illustrate the sequence of events performed when actuating the redundant fuse wire release device **10**.

The redundant fuse wire release device **10** is a fully redundant low shock release device actuated using a redundant fuse wire assembly **30**. More particularly, and referring to FIGS. **1** and **5**, the redundant fuse wire release device **10** comprises a housing **11** or fuse block **11** (FIG. **1**), a restraint release mechanism **21** (FIG. **1**), a redundant fuse wire assembly **30** (FIG. **1**), a redundant release device **40** (FIG. **5**), and an electrical power source **41**, **42** (FIGS. **4**, **7***a*, **7***b*).

The redundant fuse wire assembly **30** comprises a primary positive contact **31**, a redundant positive contact **32**, a common negative contact **33**, and primary and redundant fuse wires **34**, **35**. Each of the contacts **31**, **32**, **33** are housed in the housing **11** or fuse block **11**. Electrical wires **36** connect between the electrical power source **41**, **42** and respective contacts **31**, **32**, **33**.

The primary fuse wire **34** is connected between the primary positive contact **31** and the common negative contact **33** and wraps around the redundant positive contact **32** and rotatable restraint release arms **24**, **25**. The redundant fuse wire **35** is connected between the redundant positive contact **32** and the common negative contact **33** and wraps around the primary positive contact **31** and the rotatable restraint release arms **24**, **25**.

More particularly, the restraint release mechanism **21** comprises a top restraint pin **22**, a bottom restraint pin **23**, a top rotatable restraint release arm **24**, and a bottom rotatable restraint release arm **25**. The restraint release arms **24**, **25** are preferably made of dielectric material to prevent electrical shorting to ground. The restraint release arms **24**, **25** are free to rotate around a hinge **13**. The restraint release arms **24**, **25** are held in place under tension from tightly wound stainless steel spring restraint tapes **39** (FIG. **5**) by the primary and redundant fuse wires **34**, **35**.

Referring to FIG. **5**, the redundant release device **40** comprises a segmented spool **37** assembled on a cylindrical base **43**. The segments of the segmented spool **37** are prevented from separating by tightly wound stainless steel spring restraint tapes **39**. The restraint release arms **24**, **25** are held in tension by the restraint tapes **39** that engages the top and

bottom restraint pins **22**, **23** of the restraint release arms **24**, **25**. The restraint tape **39** are wrapped around the segmented spool **37**.

FIGS. **6***a*-**6***c* show engagement and disengagement of the restraint tapes **39** from the release arms **24**, **25**. As shown, once both fuse wires **34**, **35** are cut, both release arms **24**, **25** are free to rotate and allow the restraint tapes **39** to disengage from the arms **24**, **25** under tension provided by wound spring tapes **39**, acting as a clock spring trying to unwind.

A nut **38** and rod assembly (not shown) that is held in place by the segmented spool **37** is prevented from retracting unless the segments of the segmented spool **37** are separated. Release of either or both restraint tapes **39** allow separation of segments of the segmented spool **37** and release of nut and rod assembly. The restraint tapes **39** unwind once disengaged from the restraint release arms **24**, **25**, which are restrained from rotation by the electrically actuated redundant fuse wires **34**, **35**. The redundant fuse wire device **10** is electrically and mechanically redundant to avoid single point failure while providing simultaneous release capability.

The redundant fuse wire release device **10** provides a release function upon electrical command while offering single fault tolerant redundancy with maximum current split between the two fuses **34**, **35**. The redundant fuse wire release device **10** is used in the release device **10** as a release initiation element actuated by the electrical power source **41**, **42**.

Thus, the design of the redundant fuse wire device **10** includes two redundant fuses **34**, **35**. Both fuses **34**, **35** are cut (heated and severed) upon actuation of electrical power from power supplies **41**, **42**, thus there is no uncut fuse after actuation to pose a release hang up. Further, unlike the conventional redundant fuse wire design discussed in the Background section, where each of the three fuses may be loaded with different tension, the disclosed redundant fuse wire device **10** equalizes the tension in both fuses **34**, **35** due to flexibility of the common negative contact **33**, and thus one fuse **34**, **35** does not get overloaded.

The redundant fuse wire device **10** may be preferably configured to provide maximum current to burn both fuses **34**, **35** one at a time. The redundant fuse wire device **10** is configured as a combination of parallel and series circuitry with different fuse wire lengths to maximize the resistance difference between two parallel circuits in order to minimize the power requirement for firing both fuses **34**, **35** from a given power source **41**, **42**.

The redundant fuse wire device **10** comprises two positive contacts **31**, **32** and one common negative contact **33**. Each fuse **34**, **35** starts from a positive contact **31**, **32** and ends at the common negative contact **33** while passing over the other positive contact **32**, **31**. This arrangement provides redundancy in firing from either positive contact while providing redundancy against single fuse failure to release the restraint release arms **24**, **25**. This provides a single fault fail-safe design against premature failure of either fuse.

The redundant fuse wire assembly **30** is electrically and mechanically redundant to prevent premature release while providing simultaneous release capability. Either primary or secondary circuits fire both fuses **34**, **35** at the same time. It should be noted that the time required to burn the fuse wires **34**, **35** is in milliseconds, and that a shorter fuse wire **34**, **35** is burnt milliseconds sooner than a longer fuse wire **34**, **35**. However, for practical purposes, both fuse wires **34**, **35** are cut substantially simultaneously. The redundant fuse wire assembly **30** is preferably wired to release both top and bottom restraints **24**, **25** simultaneously, although it may be wired to release each restraint **24**, **25** individually.

The redundant fuse wire assembly has two independent fuses **34**, **35** in an overlapping configuration. Both fuses **34**, **35** must be severed in order to release the device **10**. A single fuse **34**, **35** is configured to provide at least a one-hundred percent strength margin against failure. The redundant fuse wire assembly **30** allows fuse tension balancing to eliminate possible assembly slack. The fuse block **11** provides electrical isolation for the contacts **31**, **32**, **33** and structural support for the restraint release arms **24**, **25**.

With regard to redundancy, the redundant fuse wire assembly **30** thus has two substantially identical circuits with a common negative contact **33**. The redundant fuse wire assembly **30** has two independent positive contacts and one common negative contact **33**. Actuation of either circuit fires both fuses **34**, **35**.

Referring to FIGS. **7***a* and **7***b*, they illustrate an exemplary sequence of events performed when actuating the redundant fuse wire release device **10**. Power may be applied to the primary circuit, and more current flows to the redundant fuse **35** (because the fuse wire is shorter than the primary fuse,) thus redundant fuse **35** gets cut or severed first, then full current flows to primary fuse **34** and it is cut or severed second. Motion of both release arms **24**, **25** initiate simultaneously as soon as the second fuse wire **35** is cut. However, it is to be understood that either the primary circuit or the secondary circuit may be configured to fire other fuse configurations not described herein, to enable motion of top or bottom release arms **24**, **25** separately to allow separate release of the top or bottom restraint release arms **24**, **25**.

Thus, improved redundant release devices and redundant fuse apparatus have been disclosed that may be used to stow or release items such as solar arrays, antenna positioning mechanisms, reflectors, and the like, found on satellites, space stations, and spacecraft, for example. It is to be understood that the above-described embodiment is merely illustrative of some of the many specific embodiments that represent applications of the principles of the present invention. Clearly, numerous and other arrangements can be readily devised by those skilled in the art without departing from the scope of the invention.

What is claimed is:

1. An apparatus comprising:

a restraint release mechanism comprising one or more restraint release arms;

a redundant fuse wire assembly coupled to the redundant release mechanism comprising a primary positive contact, a redundant positive contact, a common negative contact, a primary fuse wire electrically connected between the primary positive contact and the common negative contact that electrically contacts the redundant positive contact and retains the one or more restraint release arms, and a redundant fuse wire electrically connected between the redundant positive contact and the common negative contact that electrically contacts the primary positive contact and retains the one or more restraint release arms, wherein both primary and redundant fuse wires must be severed to release the one or more restraint release arms; and

an electrical power source coupled to the redundant fuse wire assembly for heating and severing the fuse wires.

2. The apparatus recited in claim **1** wherein the one or more restraint release arms comprise dielectric material.

3. The apparatus recited in claim **1** further comprising a segmented spool having a plurality of segments that are constrained from separating by spring restraint tape releasably secured to the restraint release arms, and wherein the segments of the segmented spool are prevented from separating

by the spring restraint tape, the spring restraint tape comprising tightly wound spring tape.

4. The apparatus recited in claim **1** wherein wiring of the contacts provides redundancy in firing from either positive contact and provides redundancy against single fuse failure to release the one or more restraint release arms.

5. The apparatus recited in claim **1** wherein the primary and redundant fuse wires are severed at substantially the same time.

6. The apparatus recited in claim **1** wherein the common negative contact provides flexibility to equalize tension in the fuse wires.

7. An apparatus comprising:

a restraint release mechanism comprising one or more dielectric restraint release arms;

a redundant fuse wire assembly coupled to the redundant release mechanism comprising a primary positive contact, a redundant positive contact, a common negative contact, a primary fuse wire electrically connected between the primary positive contact and the common negative contact that electrically contacts the redundant positive contact and retains the one or more dielectric restraint release arms, and a redundant fuse wire electrically connected between the redundant positive contact and the common negative contact that electrically contacts the primary positive contact and retains the one or more dielectric restraint release arms, wherein both primary and redundant fuse wires must be severed to release the one or more dielectric restraint release arms; and

an electrical power source coupled to the redundant fuse wire assembly for heating and severing the fuse wires.

8. The apparatus recited in claim **7** wherein the primary and redundant fuse wires are severed at substantially the same time.

9. The apparatus recited in claim **7** wherein the common negative contact provides flexibility to equalize tension in the fuse wires.

10. The apparatus recited in claim **7** further comprising a segmented spool having a plurality of segments that are constrained from separating by spring restraint tape releasably secured to the one or more dielectric restraint release arms, and wherein the segments of the segmented spool are prevented from separating by the spring restraint tape, the spring restraint tape comprising tightly wound spring tape.

11. The apparatus recited in claim **10** wherein the primary and redundant fuse wires are severed at substantially the same time.

12. The apparatus recited in claim **10** wherein the common negative contact provides flexibility to equalize tension in the fuse wires.

13. The apparatus recited in claim **7** wherein wiring of the contacts provides redundancy in firing from either positive contact and provides redundancy against single fuse failure to release the one or more dielectric restraint release arms.

14. A redundant fuse wire apparatus for use with a redundant release device having a restraint release mechanism comprising one or more restraint release arms and an electrical power source for heating and severing fuse wires, comprising:

a redundant fuse wire assembly comprising a primary positive contact, a redundant positive contact, a common negative contact, a primary fuse wire electrically connected between the primary positive contact and the common negative contact that electrically contacts the redundant positive contact and retains the one or more restraint release arms, and a redundant fuse wire electrically connected between the redundant positive contact and the common negative contact that electrically contacts the primary positive contact and retains the one or more restraint release arms, wherein both primary and redundant fuse wires must be severed to release the one or more restraint release arms.

15. The apparatus recited in claim **14** wherein the one or more restraint release arms comprise dielectric material.

16. The apparatus recited in claim **14** wherein the redundant release device comprises a segmented spool having a plurality of segments that are constrained from separating by spring restraint tape releasably secured to the one or more restraint release arms, and wherein the segments of the segmented spool are prevented from separating by the spring restraint tape, the spring restraint tape comprising tightly wound stainless tape.

17. The a apparatus recited in claim **14** wherein wiring of the contacts provides redundancy in firing from either positive contact and provides redundancy against single fuse failure to release the one or more restraint release arms.

* * * * *